Claims

1. A fuel cell power plant, comprising:

a fuel cell comprising an anode support plate including a porous substrate layer having an interdigitated passageway for a fuel reactant gas stream to enter therein and exit therefrom, a cathode support plate including a porous substrate layer having an interdigitated passageway for an oxidant gas stream to enter therein and exit therefrom, and a membrane electrode assembly disposed between said support plates, said membrane electrode assembly comprising a polymer electrolyte membrane disposed between two catalysts;

a first porous water transport plate adjacent to said cathode support plate, said first porous water transport plate having a passageway for a coolant stream to pass therethrough, and an interdigitated passageway for an oxidant gas stream to enter therein and exit therefrom;

a second porous water transport plate adjacent to said anode support plate, said second porous water transport plate having a passageway for a coolant stream to pass therethrough, and an interdigitated passageway for a fuel reactant stream to enter therein and exit therefrom;

means for creating a predetermined pressure differential between said oxidant gas stream and said coolant stream such that the pressure of said oxidant gas stream is greater than the pressure of said coolant stream; and

means for creating a predetermined pressure differential between said fuel reactant gas stream and said coolant stream such

that the pressure of said fuel reactant gas stream is greater than the pressure of said coolant stream.

2. A fuel cell power plant according to claim 1 wherein:

said cathode support plate comprises a porous, hydrophilic substrate layer, and a partially hydrophobic diffusion layer disposed between said substrate layer and said membrane electrode assembly;

said anode support plate includes a porous, hydrophilic substrate layer, but does not include a diffusion layer;

said water transport plates are hydrophilic; and

the pressure of said oxidant gas stream is between about 1.0 psig and about 1.5 psig above the pressure of said coolant stream.

3. A fuel cell power plant, comprising:

(a) a fuel cell comprising an anode support plate and a cathode support plate and a membrane electrode assembly disposed between said anode and cathode support plates, said membrane electrode assembly comprising a polymer electrolyte membrane disposed between two catalysts, one of said support plates comprising a substrate layer having pores therein and having an interdigitated passageway for a reactant gas stream to enter therein and exit therefrom;

(b) a porous water transport plate adjacent to said one support plate, said porous water transport plate having a passageway for a coolant stream to pass therethrough; and

(c) means for creating a predetermined pressure differential between said reactant gas stream and said coolant stream such that the pressure of said reactant gas stream is greater than the pressure of said coolant stream.

4. The fuel cell power plant of claim 3 wherein both said support plates comprise a porous substrate layer having an interdigitated passageway for a reactant gas stream to enter therein and exit therefrom and wherein said fuel cell power plant further comprises:

(d) a porous water transport plate adjacent to each of said support plates, said porous water transport plates each having a passageway for a coolant stream to pass therethrough; and

(e) means for creating a predetermined pressure differential between each said reactant gas stream and said coolant stream such that the pressure of each said reactant gas stream is greater than the pressure of said coolant stream.

5. A fuel cell power plant, comprising:

(a) a fuel cell comprising an anode support plate and a cathode support plate and a membrane electrode assembly disposed between said anode and cathode support plates, said membrane electrode assembly comprising a polymer electrolyte membrane disposed between two catalysts, said support plates each comprising a substrate layer having pores therein;

(b) a porous water transport plate adjacent to one of said support plates, said porous water transport plate having a passageway for a coolant stream to pass therethrough and an interdigitated passageway for a reactant gas stream to enter therein and exit therefrom; and

(c) means for creating a predetermined pressure differential between said reactant gas stream and said coolant stream such that

the pressure of said reactant gas stream is greater than the pressure of said coolant stream.

6. The fuel cell power plant of claim 5 wherein said porous substrate layer within one of said support plates is hydrophilic.

7. the fuel cell power plant of claim 6 wherein the pores within said hydrophilic substrate layer of said cathode support plate have a diameter such that when the pressure differential between said oxidant reactant gas stream and said coolant stream is equal to said predetermined pressure differential, a greater percentage of the pores contain oxidant gas rather than coolant.

8. The fuel cell power plant of claim 6 wherein at least 50% of the pores within said hydrophilic substrate layer have a diameter (D) that is equal to or greater than 30/P, wherein D is measured in microns and P is said predetermined pressure differential measured in pounds per square inch.

9. The fuel cell power plant of claim 6 wherein said hydrophilic porous substrate layer is a porous carbon substrate layer comprising a metal oxide, a metal hydroxide or a metal oxyhydroxide wherein said metal is selected from the group consisting of tin, aluminum, niobium, ruthenium, tantalum, titanium, zinc, zirconium, and mixtures thereof, thereby rendering said porous carbon substrate layer hydrophilic.

10. The fuel cell power plant of claim 5 wherein said predetermined pressure differential between said reactant gas stream and said coolant stream is about 0.5 psi to 10 psi.

11. The fuel cell power plant of claim 10 wherein said predetermined pressure differential between said reactant gas stream and said coolant stream is about 1.0 psi to 3 psi.

12. The fuel cell power plant of claim 11 wherein said predetermined pressure differential between said reactant gas stream and said coolant stream is about 2.0 psi to 2.5 psi.

13. The fuel cell power plant of claim 5 wherein said porous substrate layer within one of said support plates is hydrophobic.

~~14. The fuel cell power plant of claim 5 wherein said support plate further comprises a diffusion layer disposed between said substrate layer and said membrane electrode assembly.~~

15. The fuel cell power plant of claim 14 wherein said diffusion layer has critical surface energy equal to or less than about 30 dyne per centimeter.

16. The fuel cell power plant of claim 5 wherein one of said support plates does not include a diffusion layer.

~~17. The fuel cell power plant of claim 5 wherein both said support plates comprise a porous substrate layer and wherein said~~

fuel cell power plant further comprises a porous water transport plate adjacent to each said support plate.

18. The fuel cell power plant of claim 17 wherein both said porous water transport plates have a passageway for a coolant stream to pass therethrough and an interdigitated passageway for a reactant gas stream to enter therein and exit therefrom and wherein said fuel cell power plant further comprises means for creating a predetermined pressure differential between each said reactant gas stream and said coolant stream such that the pressure of each said reactant gas stream is greater than the pressure of said coolant stream.

19. A method of operating a fuel cell power plant comprising:

(a) a fuel cell comprising an anode support plate and a cathode support plate and a membrane electrode assembly disposed between said anode and cathode support plates, said membrane electrode assembly comprising a polymer electrolyte membrane disposed between two catalysts, said support plates each comprising a substrate layer having pores therein;

(b) a porous water transport plate adjacent to one of said support plates, said porous water transport plate having a passageway for a coolant stream to pass therethrough and an interdigitated passageway for a reactant gas stream to enter therein and exit therefrom; and

(c) means for creating a predetermined pressure differential between said reactant gas stream and said coolant stream such that

the pressure of said reactant gas stream is greater than the pressure of said coolant stream;

said method comprising:

flowing hydrogen-containing gas adjacent said anode support plate;

flowing air at substantially atmospheric pressure through said interdigitated passageway;

controlling the flow rate of air to maintain an oxidant stochiometry of 250% or less;

operating said fuel cell at a maximum current density of at least 1.6 amps per square centimeter in response to a corresponding electrical load across said fuel cell; and

operating said fuel cell at current densities of less than 1.6 amps per square centimeter in response to related electrical loads across said fuel cell.

20. A method of operating a PEM fuel cell system comprising a plurality of fuel cells, each having a cathode support plate, an anode support plate, a membrane electrode assembly disposed between said support plates, interdigitated oxidant flow channels on the cathode side of said membrane electrode assembly, and fuel flow channels on the anode side of said membrane electrode assembly, said method comprising:

flowing hydrogen-containing gas through said fuel flow channels;

flowing air at substantially atmospheric pressure through said oxidant flow channels;

controlling the flow rate of air to maintain an oxidant stochiometry of 250% or less;

operating said fuel cell at a maximum current density of at least 1.6 amps per square centimeter in response to a corresponding electrical load across said fuel cell; and

operating said fuel cell at current densities of less than 1.6 amps per square centimeter in response to related electrical loads across said fuel cell.

21. A method of claim 20 wherein said controlling and operating steps comprise:

operating said fuel cell at a maximum current density of at least 1.5 amps per square centimeter while controlling said flow rate to maintain a stochiometry of about 167% or less.